Construction December, 1994

The solution, says Smith, was adjusting viscosity of thedrilling fluid. 'Once we determined the correct formula, we were able to double the length of our bores.'

Construction Scares

Smith said crewmen had a few anxious moments when an old buried fuel tank was encountered. 'Fortunately, our drilling crews are HAZMAT certified andwere prepared to handle the situation if hazardous material was present.' However, this proved not to be the case, and work continued.

Another incident hardly was routine. 'We pride ourselves,' Smith says,'in being versatile enough to adapt to most elements. However, we were shut down for a few hours for an unusual reason. Killer bees.' The bees drove crew members from the job site and had to be cleared from the area before work could resume.

Cannon crews used a Ditch Witch 8160 Jet Trac(R) drilling system for much of the Texas job.

'Using the 8160,' says Smith, 'we were able to increase our daily productionrate by about 25 percent, because we were able to make longer bores and reduce restoration.'

The drill frame travels on rubber tracks andis self propelled. The compact drill frame usually did not have to occupy more than one lane of a street. During work, traffic continuedto move, because streets never had to be closed.

The 85-horsepower engine and duel fluid tanks are mounted on a truck. Hoses connect the drill frame to the hydraulic system which has 22,500 pounds of thrustand pull back power. Spindle speed ranges to 110 rpm with a torque of 1,900 foot pounds.

Each bore is launched from the surface. When the necessary depth is reached, the bore's direction is changed to a horizontal path and guided to the exit point. Bore head location, position and depth are monitored from the surface by a crew member with a electronic tracking equipment. Information is relayed to the drill operator by radio, and bore direction is adjusted as necessary.

Steering is accomplished with slant-nose drill head technology. The position of the drill head's slanted face determines the direction it travels. To continue on an established path, drill pipe is rotated. Whena direction change is required, rotation is stopped. The soil's resistance to the heads slanted face causes the head to move in the opposite direction of the slanted surface. The operator positions the head to achieve the needed change in direction, and the drill string ismoved forward. Once the designed direction is achieved, rotation isstarted.

The Cannon crew tracked the bore with a Subsite 80RP locator, also manufactured by Ditch Witch. The 80RP reads drill head location, depth and the position of the drill head.

Lengths of drill pipe are added as the bore progresses.

When the exit position is reached, a back reamer replaces the drill bit, plastic pipe is attached and pulled back through the hole. As the material comes back toward the starting point, sections of drill pipe are removed.

Drilling fluid assists the boring process (in the sandy areas encountered, fluid helped maintain walls of the bore hole) and provides lubrication in the holeduring the pull-back operation.

Experienced Contractor

Perry Spencerwas in charge of the Corpus Christi job for Cannon Construction; Scott Logerman was AT&T supervisor.

Cannon Construction has been in business eight years and has branch locations in Lilburn and Marietta, GA, and Ft. Pierce, FL. It employs 140 people. The company is a member of the Power Communications Contractors Association (PCCA). Cannonis involved in all phases of construction, including splicing, underwater construction and bridge attachments. In addition, the company does engineering work, environmental projects and is involved in realestate.

Smith says Cannon is involved in all aspects of underground construction, including trenching and vibratory plowing. The companyhas been involved in directional drilling since 1988 - about the time directional equipment became available. Cannon uses a rage of other trenchless tools, including rod pushers and pneumatic piercing equipment.

'Most of our drillers started using P80 Rod Pushers before theJet Trac 4140 series of directional drills were available,' says Smith.

Training, he says, is essential to success with trenchless technology methods. 'It's very important! You cannot be successful in the field of directional boring without special training.

'Formal instruction through Ditch Witch training programs, along with experience, the hardest and most expensive teacher, has enabled our crews to enjoy an excellent record of production.'

Smith sees an increasing commitment to trenchless methods by his company. 'As cities, municipalities and the public in general become more aware of the benefits of trenchless technology, the demand will dramatically increase. At the presenttime, we are working with several clients to utilize trenchless technology for environmental remediation which will open many areas to apply this method.'

For more information regarding products/services discussed in this article, please circle the Reader Service Number on the enclosed card:

Cable Contractor

Circle No. 184

Directional Drilling Rig

Circle No. 185

EPRI

Progressive Flexibility '97

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Transmission Conductor Applications and Advancement

Product Manager: R. Michael McCafferty
Target: Transmission & Substations
Increase power transfer, reduce upgrade costs, and operate lines at higher temperatures through improved conductors.

Improved conductors that exhibit less sag, higher strength with less weight, longer life spans, and increased corrosion resistance can help utilities increase power transfer over existing rights-of-way. They can also reduce O&M costs, cut costs for upgrades, and permit the operation of lines at higher temperatures. This project will evaluate existing and advanced materials and technologies with potential for use for conductors, prepare a feasibility report on carbon fiber and covered conductors, develop and demonstrate a covered conductor for high voltage lines, and study methods for increasing power transfer with minimum structural modifications.

Date Available: Studies of carbon fiber and covered conductors, and the conductor upgrade study, will be completed in early 1997. Specifications for a covered conductor will be completed 6/98.

[Overhead Transmission]

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[EPRI Home | Search] Last Updated: 6/24/96

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Progressive Flexibility '97

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Capacity Evaluation of Existing Foundations

Product Manager: Anwar Hirany
Email:
Target: Overhead Transmission

Cut transmission system upgrade costs by more accurately evaluating the capacity of existing foundations.

Development of a methodology for evaluating the capacity of existing transmission line foundations will enable utilities to significantly reduce upgrade costs. Structural improvements designed with reliability-based methods demonstrate transmission systems capable of handling greater loads with upgrade costs on the order of $0 to $50,000 per mile, rather than the foundation replacement costs of $75,000 to $200,000 per mile typical of present upgrades. This project will develop the new methodology and validate and refine it by performing load tests on existing foundations.

[Overhead Transmission]

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Progressive Flexibility '97

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New Extrudable Dielectrics

Product Manager: Thomas J. Rodenbaugh
Email:
Target: Underground Transmission

Retrofit existing ducts to increase ampacity, and reduce costs for new installations.
New high electric strength dielectric materials can be manufactured into thin-walled, high-ampacity cables, making it possible to retrofit existing ducts to increase ampacity. In addition, these cables could significantly reduce costs for new installations by matching the ampacity of overhead lines one-to-one, thus reducing the number of underground cables needed. Several extrudable materials will be tested to evaluate the feasibility of using them as cable dielectrics. Research will build on a previous EPRI study that identified several materials with potential for use as dielectrics.

[Underground Transmission]

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STORIES

IAC (SM) Newsletter Database (TM)
Pasha Publications Inc.
Energy Report

February 26, 1996

SECTION: No. 8, Vol. 24; ISSN: 0888-8183

LENGTH: 1101 words

HEADLINE: EPA wants utilities to prevent more air pollution after deregulation

BODY:

The Environmental Protection Agency urged the Federal Energy Regulatory Commission last week to make sure utilities don't increase air pollution from more generation when FERC opens up the wholesale market for wider electricity sales.

EPA said FERC has erroneously concluded that deregulation's effect on the environment will be minimal. EPA is worried that some utilities will burn more coal and other fossil fuels and emit more pollutants in order to sell more electricity at bargain prices when FERC opens up the wholesale market.

"The final EIS must acknowledge the possibility that economic and environmental effects of the rule could be significantly larger than predicted," EPA said in its comments on FERC's draft environmental impact statement on deregulation.

FERC should include in its final open-access transmission rule an enforceable way of prohibiting emissions increases, EPA said.

EPA wants FERC to rule that any fossil fuel-burning generator seeking to transmit power under open-access transmission tariffs is required to make a contractual commitment to avoid or offset emissions increases through emissions trading. Middlemen would have a similar obligation. Transmission entities would be required to deny service to generators that could not document such commitments. Middlemen would have to show through their contracts that their sources of generation documented they were avoiding or offsetting emissions.

To aid mitigation, FERC should make sure contracts for power sales include real-time posting of emissions information on electronic bulletin boards, EPA said.

Virtually all generation sources already are required to report nitrogen oxide NOx and carbon dioxide CO2 emissions under the Acid Rain Program.

Alternatively, EPA could establish a procedure for generators to assure compliance to EPA and/or state environmental authorities.

EPA essentially said FERC is attempting to dodge its responsibility.

The draft EIS "sets out a falsely restrictive view of FERC's statutory authority to adopt measures for mitigating adverse environmental impacts" of the proposed rule for deregulation, EPA said.

"FERC bears the responsibility for preventing emissions increases related to its actions promoting competition in electricity markets and must therefore support specific mitigation mechanisms," the agency said. "EPA looks forward to working with FERC to carry out this important duty."

The Federal Power Act requires FERC to act in the public interest, and the National Environmental Policy Act requires federal agencies, such as FERC, to use all practicable means to avoid environmental degradation, EPA said. EPA noted FERC established a precedent in taking environmental effects of cogeneration and small power production into account as it established rules under the Public Utility Regulatory Policies Act in 1981. "Because of its concern that diesel and dual-fuel commercial cogeneration facilities in New York City had the potential to cause environmentally significant effects, the FERC issued regulations that excluded new diesel cogeneration facilities," EPA said.

Electric power plant emissions are substantial contributors to the nation's most significant public health and environmental concerns, EPA said. In 1993 power plants caused 72% of all sulfur dioxide (SO_2) emissions, 33% of NOx, 23% of mercury emissions and 32% of particulates.

"The proposed open access rule as presently structured would lead to significant increases in three pollutants that are of primary concern to EPA: NOx, mercury and CO_2," EPA added. "The projected increases in NO_2 emissions attributed to the proposed access rule will adversely impact air quality in places where the air is already unhealthy," EPA concluded. More transmission capacity likely

The nation's top environmental enforcement agency said FERC's draft EIS failed to consider the possibility that utilities will have incentives to make investments in transmission that will boost the output of polluting plants more than FERC assumed under current transmission constraints.

"The proposed open access rule also provides significant financial incentives for utilities to expand transmission capacity," EPA said. "Transmission owners are given the opportunity to earn increased profits through an increase in transmission volume, thereby providing an additional incentive for new transmission investment."

Yet FERC implies siting barriers at the state and local level will block new lines from being built. "This assumption is unreasonable in that new transmission lines are, in fact, sited and built every year in this country despite the existence of siting barriers," EPA said.

Further, technologies are available to expand transmission capacity without building new lines, the agency said. New lines in existing corridors can be upgraded. Flexible AC Transmission

~~Systems can increase power flow in certain lines by 50%, EPA noted,~~ quoting the Electric Power ~~Research Institute.~~

EPA said the central tenet of the Clinton administration is that "a strong economy and strong environment go hand in hand."

And the agency warned it will impose its own controls, if necessary. "EPA stands ready to use that authority as needed." But the regulations under the

STORIES

Modern Power Systems

April, 1996

SECTION: Vol. 16 ; No. 4 ; Pg. 57; ISSN: 0260-7840

LENGTH: 2563 words

HEADLINE: Unified power flow controller: the ultimate FACTS device; Flexible AC Transmission System

BYLINE: Stahlkopf, Karl E.

BODY:

Increasing acceleration of electricity sales will place a strain on the highly interconnected North American power grid, which will be expected to perform functions well beyond its original design capacity, at a time when there is little or no incentive for construction of new transmission facilities. Similar challenges are also arising in many other areas of the world. Such changes can best be accommodated by timely use of advanced power flow control technologies, and the most versatile of these is the Unified Power Flow Controller (UPFC).

The global electric power industry is being transformed by an unprecedented combination of political and economic forces, and by technological opportunities. In the United States, deregulation at both the federal and state levels is bringing individual utilities face to face with the challenges of increased competition.

At the same time, utilities are being transformed by privatization, reorganization, and formation of international alliances. New technologies can help each of these utilities cope with the transition ahead, particularly in the area of power delivery.

In many parts of the world, the forces of change have come to focus on bulk power delivery systems because of wide disparities in the cost of electricity among neighbouring regions. Retail rates for electricity in the United States, for example, are more than four times higher in some parts of the country than in others, and even within individual states they may vary by a factor of two.

Such discrepancies contributed to the passage, in 1992, of the National Energy Policy Act (NEPA), which requires utilities to provide transmission access to third-party producers. Acting under authority provided by NEPA, the Federal Energy Regulatory Commission recently issued a Notice of Proposed Rulemaking - widely known in the industry as the "Mega-NOPR" because of its size and complexity - which sets forth terms and conditions for opening the wholesale electricity market to competition.

As a result of these changes, the volume of bulk power transactions carried by US transmission systems is expected to grow substantially over the next several years. Already, about 40 per cent of electricity generated in the United States is sold on the wholesale market before it is distributed to retail customers ILLUSTRATION FOR FIGURE 1 OMITTED .

Further acceleration of such sales will place a strain on the highly interconnected North American power grid, which will be expected to perform functions well beyond its original design capacity, at a time when there is little or no incentive for construction of new transmission facilities. Similar challenges are also arising in many other areas of the world. This paper argues that such changes can best be accommodated by timely use of advanced power flow control technologies, and that the most versatile of these is the Unified Power Flow Controller (UPFC).

Flexible AC transmission system

A fundamental fact about today's transmission systems is that the flow of power on individual lines is difficult to control. The result is loop flows and bottlenecks. In addition, when voltage disturbances arise on the transmission grid, the present generation of mechanical controllers react too slowly to keep them from spreading. Because of these control limitations, line capacity may be constrained by system stability considerations rather than by thermal limits.
Fortunately, a new generation of high-power electronic devices is becoming available that will give utilities an unprecedented level of control over the flow of electricity through their transmission systems. These power electronic controllers can facilitate a fundamental redesign of power delivery systems, enabling utilities to direct power flows along specific corridors and increase line capacity nearer to inherent physical limits.

For many years, the Electric Power Research Institute (EPRI) has pioneered the use of such power electronic controllers to form the basis of a Flexible AC Transmission System (FACTS). This research effort is now paying off for far-sighted utilities participating in demonstrations of FACTS technology.
What we now consider the first FACTS device - although that term had not yet been coined - was the Static VAR Compensator (SVC), which EPRI helped bring to market nearly twenty years ago. The SVC consisted of a fast thyristor switch controlling a shunt capacitor bank, which helped provide voltage support for heavy loads near the end of a line. It also contributed to system stability but did not control power flow directly.

Later members of this first generation of FACTS devices provide series compensation using conventional thyristors to control a capacitor bank connected in series with a line, thus enabling a utility to increase power flow on particular lines over longer distances.

Testing of the first, single-phase Thyristor-Switched Series Capacitor (TSSC) began in 1991 by the American Electric Power Company. In 1992, the Western Area Power Administration installed a three-phase Thyristor-Controlled Series Capacitor (TCSC), that enabled them to increase the capacity of a transmission line from 300 MW to 400 MW. The world's largest TCSC, with a full range of features, has been operating at Bonneville Power Administration since 1993, with EPRI participation.

Recently, the first utility demonstration of a second generation FACTS device began. Controllers of this and subsequent generations can perform the voltage support and power control functions of previous devices - but without the need for large external circuit elements. Rather, by using an advanced configuration of gate turn-off (GTO) thyristors, these new devices can mimic reactors and capacitors electronically - potentially reducing the cost of FACTS applications while improving their performance considerably.

In November, 1995, the first Static Synchronous Compensator (STATCOM) began operation at the Sullivan substation of the Tennessee Valley Authority, near Johnson City, Tennessee ILLUSTRATION FOR FIGURE 2 OMITTED . This second-generation FACTS controller provides voltage support to a transmission line by generating or absorbing reactive power through an all-electronic shunt connection.

In addition, STATCOM can respond quickly to damp major disturbances on the power system. The + or - 100 MVAR STATCOM is an investment of $ 10 million, but if it was not installed, a $ 20 million transformer bank would be necessary. It will also enable TVA to avoid building a new 161 kV transmission line into the Johnson City area.

UPFC operation

Now, a third-generation FACTS controller - the Unified Power Flow Controller (UPFC) - has been developed by EPRI and Westinghouse Corp. UPFC will be the first FACTS device that can control all three parameters of power flow - voltage, line impedance and phase angle - simultaneously. This combination of functions gives the UPFC a unique capability to control simultaneously both real and reactive power flows on a transmission corridor.

A UPFC consists of two voltage-sourced inverters based on GTO thyristors, connected by a common dc link that includes a storage capacitor ILLUSTRATION FOR FIGURE 4 OMITTED . One inverter is connected in series with the transmission line and provides the main function of the UPFC by injecting an ac voltage with controllable magnitude and phase angle.

The second inverter is connected to the line as a shunt and its basic function is to supply or absorb the real power demanded by the series inverter, through the common dc link. Both inverters are capable of independently exchanging internally-generated reactive power with the line.

The versatility of a UPFC compared to previous control devices is shown in Figure 5. Bold letters represent phasors and dotted lines indicate the range of control provided by each device for a given input voltage. A voltage regulator (a), such as a transformer with tap-changer, injects a voltage Delta V in phase with the original voltage V.sub.0 to increase the magnitude of the outgoing voltage V.

A series compensation device (b), such as a TCSC, affects the magnitude of the current flowing through the transmission line by changing the line impedance - equivalent to injecting a voltage V.sub.c in quadrature with the current phasor I. Phase shifting (c) is usually accomplished using a angle-regulating transformer, whose action is equivalent to injecting a voltage V_s in quadrature with the original voltage V_0, which does not practically change the magnitude of V_0.

In contrast to such single-function controllers, a multi-function UPFC (d) can vary all of these parameters simultaneously by injecting a voltage

V.sub.pq with variable magnitude and angle, which provides a unique ability to control both the real and reactive power of a line independently.

In a utility application, the control system of the UPFC can be set to maintain a prescribed level of real and reactive power on a line, using continuous feedback control. In this configuration, it automatically adjusts the injected voltage to compensate for load changes on the line, such as start-up of a heavy industrial assembly line.

In addition, the UPFC can react quickly enough (in approximately a quarter cycle) to damp power oscillations, such as subsynchronous resonance, and this will improve overall system security. These capabilities open a new range of power control options, including local operation using a graphical interface or automatic operation in response to instructions from a utility centre.

UPFC application

The first UPFC in utility service will be installed by the American Electric Power Co. (AEP) at their Inez substation in eastern Kentucky. The Inez area is rural and has been experiencing substantial load growth associated with coal mining, which accounts for 85 per cent of industrial electricity demand in the area.

At present, the Inez area transmission network is the most heavily loaded and stressed on the AEP system, with power demand of approximately 2000 MW served by long 138 kV transmission lines. Many of these lines have experienced flows reaching 300 MVA - a level that is well above the desirable surge impedance loading and that leaves little margin for system contingencies.

As a result, voltages within the Inez area transmission network may fall as low as 95 per cent of nominal rating, considered the lowest acceptable level for reliable service. Computer simulations indicate that more than 30 different combinations of double contingency outages on the network could result in area-wide blackouts.

Double contingency outages in the neighbouring Tri-State area to the north could also lead to potential problems. Clearly an integrated system solution was needed to resolve weaknesses in both the Inez and Tri-State areas.

To meet this need AEP will build a new high-capacity 138 kV line between a power plant in the Tri-State area and the Inez substation. The UPFC located at Inez will provide load flow control to fully utilize the capacity of the new line and will also provide voltage support to reinforce service in the heavily industrialized Tri-State area.

Together, the new line and the UPFC offer a cost-effective approach for balancing the diverse needs of the winter-peaking Inez area, and the summer-peaking Tri-State area, increasing power flow into the former and improving system security in the latter.

Installation at AEP

The Inez UPFC will be installed in two phases. A + or - 160 MVA shunt inverter, expected to enter service by late 1996, will function initially as a STATCOM, providing reactive power and dynamic voltage support. It will also control the switching operations of several conventional shunt capacitor banks in the Inez area.

By late 1997, the 138 kV line and the + or - 160 MVA series inverter of the UPFC will be added, together with two more conventionally switched shunt capacitor banks. (The presence of the UPFC permits use of additional capacitance in the network, since the controller can quickly damp any resonant oscillations that might otherwise occur.)

Both inverters will have an identical design and will perform different functions only by being connected to the 138 kV line by a shunt transformer and a series transformer, respectively. At the Inez installation, a spare shunt transformer will also be provided, which will allow both inverters to be used for shunt compensation - if needed - up to a total of + or -!320 MVA.

During normal operation, the UPFC will control flow on the new 138 kV line so that it carries approximately 300 MW power, to realize least-loss loading for the overall network. During contingency conditions, however, the UPFC can be used to maximize loading on the line, which will have an ultimate thermal capacity of about 950 MVA.

A major advantage of UPFC technology is that these controllers are built with standardized electronic components, without the need for large external circuit elements, such as capacitors or reactors. This design permits a much smaller installation "footprint": the Inez UPFC, for example, will occupy a standard commercial building with metal walls and roof covering 100 feet x 200 feet (30 m x 60 m) - compared to a typical TCSC, which requires an area the size of a football field.

The use of thyristor-based components that represent the bulk of the capital investment will also enable the cost of the UPFC to decline as the price of power electronics continues to fall, as expected.

Transmission system of the future

Eventually, multiple FACTS controllers will be used in a coordinated fashion to improve the performance of whole transmission networks. AEP, in particular, intends to deploy several more UPFCs in a centrally controlled fashion across their seven-state transmission system.

Among the advantages of such system-wide application is that it will provide the most powerful method yet devised to combat loop flow. American Electric Power, for example, has sometimes had to carry part of the electricity generated by hydroelectric facilities in eastern Canada and destined for New York City - even though AEP's transmission system is hundreds of miles to the west of the contract path. Being able to control the flow of power more precisely, using multiple UPFCs, will enable the utility to counteract the problem of loop flow by relieving overloaded lines and directing more power onto underutilized lines.

Such enhanced control will also make it easier for utilities to handle the increased volume of bulk power transactions and to provide ancillary services for such transactions, as specified by the Mega-NOPR. In this way, FACTS can help utilities cope with the wave of increased competition now sweeping over the global electric power industry, improving network reliability and potentially lower electricity rates for customers.

Modern Power Systems,

April, 1996

Within just a few years, electricity will probably flow through thyristor-based controllers multiple times on its way from a power plant to homes and offices. Although various FACTS devices will probably continue to find applications to meet specific utility needs, by far the most versatile of these controllers is the UPFC, which is therefore expected to eventually dominate the field.

GRAPHIC: Photograph; Chart; Graph

SIC: 3610 Electric Distribution Equipment

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 Electric Light & Power

March, 1996

SECTION: FOCUS; On Transmission Control Centers; Pg. 19

LENGTH: 3309 words

HEADLINE: New transmission control systems optimize power flow
BYLINE: Wayne Beaty, Managing Editor

BODY:
The vast, interconnected North American power grid -- in which electric generators, separated by thousands of miles, must move together with split-second synchronism -- has been called the greatest and most complex machine ever created.

The steady growth of system loads combined with delayed or canceled new lines have stretched the existing transmission systems to the limit. This condition has created new requirements for load flow control, system stability and capacity enhancement. Deregulation, which opens up the transmission grid to wholesale markets, will further challenge the original design capabilities of this vast system.

The retail power market is also undergoing profound changes, as state deregulation gives consumers greater choice among electricity providers. At the same time, consumers are increasingly concerned about power quality -- since even momentary disturbances that would previously have gone unnoticed may now cause computers and other digital equipment to malfunction.

A global problem

More efficient control of the transmission grid is not just a North American problem. Wolfgang Schroppel, Siemens Power Systems Control's manager of Global Development says, "In the environment of deregulation and privitization, transmission systems must be enhanced with control systems that optimize operations. Engineers can no longer use old technology but must maximize usage through new algorithms and new devices developed through research."

Schroppel emphasized that partnerships must be developed between utilities and vendors that would shorten development time for new technologies. Risks could be shared and knowledge and experience leveraged to bring about more intelligent use of the investment in transmission systems.

Jon Scudder, Manager of Applications Development and Delivery for Siemens, says. "The fundamental motivation for the use of the transmission resources is becoming increasingly economic. Reliability, previously the only real concern in system operations design, may become dominantly viewed as simply an impediment to successful commerce. The key to maximizing the reliable use of the transmission assets lies in the application of technologies that provide a higher degree of system controllability -- namely, thyristor-controlled devices and automation systems coordinated from the local device level all the way through regional transmission operations.

Electric Light & Power,

March, 1996

Research pays off

The development of tiny integrated circuits on silicon chips has changed all of our lives. The proliferation of microelectronic processors has increased the vulnerability of many kinds of equipment to power quality problems. Before the introduction of microelectronics, minor variations in voltage did not cause any problems but now may completely shut down a factory. An outage of less than one cycle or a voltage sag of 25 percent for just two cycles can cause a microprocessor to malfunction.

A new technological development that is having a profound impact in helping utilities reduce costs and provide better service involves new ways to control the flow of ac power over existing transmission networks.

A new generation of high-power electronic devices is now available that will give utilities an unprecedented level of control over the flow of electricity through their substations (Figure 1) and transmission and distribution systems. The thyristor-based controllers offer the same advantages of speed and precision as integrated circuits, but scaled up by a factor of some 500 million in power.

These controllers will facilitate a fundamental redesign of power delivery systems, enabling utilities to increase utilization of their present assets and to provide customers with the level of power quality they need.

The pioneering efforts of utilities, manufacturers and research organizations in developing these high-power electronics have alleviated to some extent the constraints imposed on bulk power systems.

FACTS technology

A basic fact about electricity is that it flows in paths governed only by physical laws, not where we want it to. The result of this phenomena is that some lines are overloaded and some are underloaded. Loop flows occur and bottlenecks in the system limit the capacity of particular lines. Additionally, voltage disturbances on transmission lines are difficult to control fast enough to keep them from propagating.

Because of these control limitations, line capacity is usually constrained by system stability considerations rather than by inherent limits.

About 20 years ago, the Electric Power Research Institute (EPRI) started work on using power electronic controllers deployed to create a Flexible ac Transmission System (FACTS). This technology was designed to solve both problems -- load flow and power quality. FACTS would enable utilities to direct power flows along specific routes and increase line capacity nearer to the thermal limits of the line.

Utilities are now demonstrating this technology in various forms and locations.

The first FACTS device -- although that term had not yet been coined -- was the Static var Compensator (SVC) that EPRI helped bring to market nearly 20 years ago. The SVC consisted of a fast thyristor switch controlling a shunt capacitor bank, which helped provide voltage support for heavy loads near the